California Division of Mines and Geology
Fault Evaluation Report FER-172
Southern Newport-Inglewood Fault Zone,
Southern Los Angeles and Northern Orange Counties

by

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INTRODUCTION

Potentially active faults located in southern Los Angeles and northern Orange Counties that are evaluated in this FER form the Newport-Inglewood fault zone and include the Seal Beach, North Branch, Bolsa-Fairview, South Branch, Adams Avenue, Indianapolis, Yorktown, and other associated faults (figure 1). Some of these faults were zoned for Special Studies in 1976 in the Los Alamitos and Seal Beach 7.5-minute quadrangles (CDMG, 1976a, 1976b). Some faults in these quadrangles may not be Holocene active and most of the zones appear to be unnecessarily wide. In addition, faults that may be active (Holocene) were not zoned in 1976 (e.g. parts of the Seal Beach and Newport Beach quadrangles). These faults are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The northwestern coastal Orange County study area is characterized by a tectonic regime dominated by strike-slip faulting along elements of the San Andreas fault system. Topography in the study area is generally subdued, ranging from the flat floodplains and marshland of the San Gabriel and Santa Ana rivers to a series of low hills and mesas aligned along a general northwest trend. Elevations in the study area range from sea level to about 120 feet. Development in the study area is extremely heavy; the earliest aerial photographs (1927) do not predate the extensive oil field development along the Newport-Inglewood fault zone.

Predominant rock types exposed in the study area include Miocene and Pliocene marine sedimentary rocks, lower Pleistocene San Pedro Formation, upper Pleistocene Lakewood Formation, and Holocene alluvium (Poland and others, 1956; CDWR, 1966, 1968). Pleistocene sedimentary rocks underlie the low mesas which include (from north to south) Bixby Ranch Hill, Landing Hill, Bolsa Chica mesa, Huntington Beach mesa, and Newport mesa (figure 1). These mesas, which represent an uplifted late Pleistocene surface (Poland and others, 1956) are separated by water gaps cut by the San Gabriel and Santa Ana rivers during the last low stand of sea level (17-20Ka) (Davis, 1981; Poland and others, 1956). The water gaps, known as the Alamitos, Sunset, Bolsa, and Santa Ana gaps (figure 1), have been backfilled with Holocene alluvial floodplain, lagoonal, and tidal marsh deposits (CDWR, 1966, 1968).

The Newport-Inglewood fault zone extends for about 70 km from Newport mesa northwest to the Cheviot Hills along the western side of the Los Angeles Basin (Barrows, 1974). The Newport-Inglewood fault zone, which was originally zoned for Special Studies in 1976, will be re-evaluated in two Fault Evaluation Reports (FER's). This FER will evaluate segments of the Newport-Inglewood fault zone in the Los Alamitos, Seal Beach, and Newport Beach 7.5-minute quadrangles (figure 1).

The Newport-Inglewood fault zone consists of a series of northwest-trending, generally right-lateral strike-slip faults. Individual faults at, or near, the surface within the zone form short, discontinuous, generally left-stepping en echelon patterns. Associated northwest- to west-trending, right-stepping anticlinal folds, and numerous short subsidiary normal and reverse faults form what has variously been termed the Newport-Inglewood structural zone (Barrows, 1974), Newport-Inglewood zone of deformation (WCC, 1979), Newport-Inglewood uplift, or the Newport-Inglewood zone of flexure. For purposes of this report, the term Newport-Inglewood fault zone will be used because only those faults at or near the surface will be evaluated.

Harding (1973) considered the Newport-Inglewood fault zone to typify the wrench-tectonic style of deformation. Evidence for wrench deformation cited by Harding includes: (1) laterally offset fold axes and fold flanks; (2) horizontal slickensides observed along faults (well core data); (3) juxtaposed dissimilar stratigraphies; (4) variable nature of fault zone; (5) en echelon fold and fault pattern; (6) strike-slip genesis of associated secondary structures; and (7) parallel trend with documented wrench faults (i.e. San Andreas fault). The relatively small displacements of fold axes and the lack of a through-going fault in the sedimentary cover (Quaternary deposits?) indicated to Harding that the Newport-Inglewood fault zone is in the early stages of structural development (after Wilcox and others, 1973).

The magnitude of right-lateral offset along the Newport-Inglewood fault zone is not well known. Harding (1973) indicated that right-lateral strike-slip displacement of structural axes ranges from 180 to 760 meters. Hill (1971) reported that offsets of Miocene, Pliocene, and Pleistocene lithofacies seem to confirm right-lateral displacements of up to 3 km. Hazenbush and Allen (1958) suggested that the maximum horizontal deformation along the Newport-Inglewood fault zone may total more than 9-1/2 km since middle Miocene time. Woodward-Clyde Consultants (WCC, 1979) estimated that up to 3-1/2 km of right-lateral displacement has occurred along the fault zone since late Miocene time.

WCC (1979) calculated a slip-rate of about 0.5 mm/yr along the southern Newport-Inglewood fault zone, based on correlation of E-log data in the Seal Beach and Huntington Beach oil fields. The 0.5 mm/yr slip-rate represents fault displacement since late Miocene time, and it is not certain how this slip-rate relates to late Quaternary slip-rates. It was found that segments of the Newport-Inglewood fault zone in Huntington Beach, Seal Beach, Long Beach, and the Baldwin Hills are all characterized by long-term slip-rates of about 0.5 mm/yr (Guptill and Heath, 1981). It was also concluded that the ratio of horizontal slip to vertical slip was about 20:1 (WCC, 1979).

Clark and others (1984) assigned a preferred late Quaternary slip-rate of about 0.6 mm/yr along the North Branch fault in the Bolsa gap area. Clark and others emphasized that there were significant to major uncertainties involved with the estimates of maximum slip along the fault. It was also noted that the slip-rate is based on apparent vertical separation of the Bolsa aquifer; horizontal slip is not known.

SEAL BEACH AND NORTH BRANCH FAULTS

Northwest of the study area, the principal active trace of the Newport-Inglewood fault zone is delineated by the northwest-trending Reservoir Hill fault (figure 1). The Newport-Inglewood fault zone is characterized by a single trace (Seal Beach fault) in the northwest corner of the study area, but splays into many branches in the central and southeastern parts of the study area (figure 1). The Seal Beach fault of Bowes (1943) is considered to be continuous with the Reservoir Hill fault by both Bowes and Poland and others (1956). In the Bolsa gap area the Seal Beach fault splays into several branches, the North Branch fault (also known as the High School fault) being considered the principal fault trace. The North Branch fault is probably the southeastern extension of the Seal Beach fault (Willis 1958; WCC, 1984). In order to facilitate discussion in this report, the Seal Beach fault is considered to extend into Sunset gap and the northwestern part of the North Branch (High School) fault is considered to begin at Bolsa Chica Mesa.

Bixby Ranch Hill - Sunset Gap

Traces of the Seal Beach and North Branch faults in the Bixby Ranch Hill-Sunset gap area were zoned for Special Studies in 1976, based on mapping by Poland and others (1956) and California Department of Water Resources (CDWR, 1968) (figure 2a). Poland and others (1956) did not recognize the Seal Beach fault as a strike-slip fault, but rather, as a steeply northeast-dipping normal fault. Late Pleistocene deposits are offset along the fault on Bixby Ranch Hill, Landing Hill, and Bolsa Chica mesa, but Poland and others did not observe evidence of Holocene offset. However, the 1976 zone maps were based on evidence of Quaternary activity (compared to the current Holocene criterion). Zeilbauer and others (1961) postulated that late Pleistocene offset along the Seal Beach fault was left-lateral strike-slip. However, this sense of offset is not compatible with the regional tectonic style and trend of the Seal Beach fault. California Division of Oil and Gas (CDOG) summaries (CDOG, 1974) indicated that the Seal Beach oil field is characterized by a through-going, northwest-trending, right-lateral strike-slip fault.

CDWR (1968) mapped the Seal Beach fault as offsetting late Pleistocene deposits in Landing Hill and Bolsa Chica mesa. Late Holocene alluvial deposits at the surface are not offset in the Alamitos and Sunset gaps (figure 2a). Data presented in cross section E-E' (CDWR, 1968) are not clear regarding offset of Holocene deposits because there is a lack of well control on the southwest side of the fault. However, there is a strong salinity contrast in ground water in Pleistocene and Holocene alluvial deposits on the southwest side, indicating that a geological barrier of some kind exists within about 900 meters of the mapped trace of the Seal Beach fault. The location of the surface trace of the Seal Beach fault in Sunset gap was inferred based on the location of two small hillocks assumed to be underlain by late Pleistocene deposits (Hog Island and a small hillock in the Huntington Harbor area) (Poland and others, 1956; CDWR, 1968) (localities 1, 2, figure 2a).

Two site-specific fault investigations that have been performed along the Seal Beach fault include Davis (1981) and Fisher and Stoney (1983) (figures 2a, 3a). The Davis (1981) investigation located the Seal Beach fault in a trench excavation (trench A) across a linear swale on Landing Hill (figure 2a). The fault offset the base of a paleo B soil horizon about 8 to 10 cm (apparent vertical separation). The age of the paleosol was estimated to be about 125,000yr old. The top of the paleosol also was reported to be offset and the relative soil profile development suggested that the soil formed approximately 35,000 to 50,000ybp. Traces of the fault extended upward into the C_2 horizon. It is possible that the fractures continued into the modern solum, but extensive modification due to rodent burrowing and artificial fill have obscured soil-fault relationships. It was concluded that displacement along the Seal Beach fault continued through late Pleistocene time, probably to within the last 15,000 to 20,000 years ago (Davis, 1981). The sense of apparent vertical separation (down-to-the-southwest) doesn't appear to coincide with the geomorphic expression of the fault at Landing Hill (generally a northeast-facing scarp). However, there may be very little component of vertical offset along the fault and the anamolous vertical separation can be explained by right-lateral strike-slip offset of a gently sloping surface. The magnitude of lateral offset could not be determined.

Fisher and Stoney (1983) excavated trenches across the Seal Beach fault on U.S. Navy property located about 600 meters southeast of the Davis (1981) site (figure 2a). Trenches 3 and 4 exposed faulted late Pleistocene Lakewood Formation. The near-vertically dipping fault had a strike of N50°W, consistent with the fault exposed at the Davis (1981) site and the general trend of the Seal Beach fault delineated by oil field data, and from seismic refraction data performed by Fisher and Stoney (1983). Evidence of Holocene faulting was not observed in the excavations. The "topsoil" unit exposed in trench 4 is not offset; however, the topsoil unit was not evaluated in detail so the relative age of the soil unit is unknown. Fisher and Stoney concluded that evidence of recent surface rupture was not observed in trenches 3 and 4.

A sparker-arcer geophysical survey was conducted by Alpine Geophysical Associates, Inc. in the Huntington Harbor area of Sunset gap for Bechtel (1967). The seismic reflection survey identified the Seal Beach fault in the subsurface of Huntington Harbor. The fault could be traced from a depth of 150 meters below sea level "upward through the surface layers". Merrill (1977) located the fault by seismic profiling at a depth of about 18 meters. Evidence of offset late Holocene deposits was not reported in a 5.8-meter-deep trench exposure across this fault at the same locality (Freeman, Benfer, and Merrill, 1976) (figure 2a, Table 1). A fossil shell horizon exposed in the excavation at a depth of about 2 meters was radiometrically dated at 1245 $\pm$ 100 ybp.

Bolsa Chica Mesa and Bolsa Gap

The North Branch (High School) fault in the Huntington Beach oil field is characterized by a through-going, right-lateral strike-slip fault (Hazenbush and Allen, 1958) (figure 2a). An approximately 120-meter-wide "shatter zone" located in Bolsa gap represents a left-step in the fault zone (locality 3, figure 2a). Poland and others (1956) mapped the North Branch fault in Bolsa Chica mesa, based on an abrupt southwest-facing escarpment in late Pleistocene deposits (locality 4, figure 2a). CDWR (1968) mapped an approximately 275-meter-wide zone of concealed faults they considered to be the North Branch fault. WCC (1984) exposed evidence of Holocene-active faulting along the North Branch fault on Bolsa Chica mesa (figures 2a, 4). A thick B soil horizon is offset and, in trench T-2, the A soil horizon appears to be offset along a moderately to steeply northeast-dipping fault (figure 4). However, the relationship between the fault and the A soil horizon was not clear on the opposite side of the trench according to P. Guptill (p.c., June 1985). The fault was also observed by WCC (1984) in a cut slope along the southeast side of Bolsa Chica mesa (figure 2a). The fault offsets both the B and A soil horizons, consistent with the offset exposed in trench T-2 (figures 2a, 4).

CDWR (1968) showed the Bolsa aquifer, an early Holocene deposit, as offset along the North Branch fault in cross section G-G' (near locality 5, figure 2). An approximately 6-meter apparent vertical offset (northeast side down) of the Bolsa aquifer was interpreted from wells BSO-1A and NB-1. These wells are located about 335 meters apart and are the only shallow control points in Bolsa gap. CDWR stated that the apparent vertical offset could be due to normal stratigraphic discontinuities or a meander in the ancient stream channel. However, there is a marked contrast in salinity in ground water across this inferred fault and ground water elevations are different across the inferred fault (CDWR, 1968; WCC, 1984). WCC (1984) concluded that the width of the 275-meter-wide zone of faults comprising CDWR's North Branch fault could not be supported, based on the widely spaced water well control points.

Huntington Beach Mesa

Prior to investigations by WCC (1984), the location of the North Branch fault across Huntington Beach mesa was not clearly known. Poland and others (1956) had inferred a fault across the mesa, based mainly on oil-field information and some general geomorphic features (figure 2a). CDWR (1968) based the location of the principal trace of the North Branch fault on topographic expression, inferring from 6 to 12 meters of vertical offset of the upper Pleistocene land surface. CDWR (1968) mapped two additional faults on the mesa, but it is not clear what evidence was used, other than a continuation of the faults inferred from water well data in Bolsa gap (figure 2a).

Miller and others (1975) mapped the North Branch fault as a concealed trace across Huntington Beach mesa. This fault was generally based on Poland and others (1956) (figures 2a, 2b). Miller stated that he was unable to verify a throughgoing fault across Huntington Beach mesa.

An investigation by Dames and Moore (1974) failed to locate the North Branch fault in one 108-meter-long trench and 3 test pits in late Pleistocene deposits (figure 2a). Dames and Moore concluded that no faulting comes within 1,000 feet of the ground surface. Dames and Moore based the location of their trench on oil field data from Chevron U.S.A.

Keaton (1975) located what he called minor faulting in the Huntington Beach mesa, but he did not locate a main trace, based on exploratory borings (figure 2b). Keaton (1975) concluded that the trace of the North Branch fault is located north of boring 3 (figure 2b). Keaton observed several small faults in a railroad cut north of 17th Street (locality 6, figure 2b). Only one fault was continuous and observable on both sides of the railroad cut. This fault had an apparent down-to-the-south vertical offset of about 3 cm in late Pleistocene deposits. The deposits are thought to be greater than 40,000y old, based on radiocarbon dating. Evidence of Holocene offset was not observed, according to Keaton. R. Miller (p.c. June 1985) stated that the faults exposed in the railroad cut seemed to be minor faulting and that the principal fault was located a short distance to the south. Miller reported that late Pleistocene sediments and an old soil horizon (paleosol?) are anticlinally folded (arched) across this small hill, indicating that it is a pressure ridge.

WCC (1984) logged several cut slopes and trenches along the North Branch fault along the west edge of Huntington Beach mesa (locality 7, figure 2a). A zone of faulting about 24 meters wide was observed in cut slope C-1 (figures 2a, 5). A marine sand unit contained fossils, which suggested an age of the sand of about 120 ka (WCC, 1984). This marine sand unit could not be correlated across the fault, indicating a significant, though indeterminant, amount of lateral or vertical offset. The principal fault zone, which consists of 3 near-vertical shears, apparently does not offset an overlying B soil horizon. However, WCC (1984, p. 24) stated that some traces of the major fault zone could be traced up into the base of the soil zone, but that the soil had been highly disturbed by animal burrowing. In addition, old oil field grading operations have disturbed surface and near-surface conditions.

Cut slope C-2 revealed a fault zone about 14 meters wide. Faults are vertical to near-vertical, and the principal fault trends N55°W (figure 6). A siltstone bed has an apparent vertical offset of 1.4 meters (down-to-the-southwest). A sand unit (units 8 and 13) overlying the siltstone exhibits different facies across the fault, indicating that an undetermined amount of lateral offset has occurred. The fault can be traced up to the base of a B soil horizon. Although the B horizon is noticeably thicker on the southwest side of the fault, rodent burrowing has obscured soil-fault relationships. However, a C horizon mapped on the southwest side of the fault was not continuous across the fault, indicating that faulting may involve the modern soil.

Additional small faults were reported in trenches T-1, T-2, and T-3. Minor, apparently vertical displacements with both normal and reverse senses of offset were reported. WCC (1984) interpreted these features as minor faults probably related to regional uplift and folding of the Pleistocene sediments and stated that they are not related to deep-seated faulting in either trend or spatial association. However, one minor fault exposed in T-2 offsets the base of a B soil horizon about 1 cm. The trend of this fault is N35°W (figure 2a).

Santa Ana Gap - Newport Mesa

Poland and others (1956) mapped a single, concealed trace of the North Branch fault in Santa Ana gap, based on water-well and oil-well data (figure 2b). CDWR (1966) mapped a complex zone of faults comprising the North Branch fault in Santa Ana gap that are based on water-well data. The principal trace of the North Branch fault is bracketed by wells about 30 meters apart. The Talbert aquifer, a lower Holocene deposit, is not offset along the North Branch fault as depicted in CDWR (1966) cross sections B-B' and C-C'. The North Branch fault forms a salinity barrier in late Pleistocene sediments, but the Talbert aquifer has a very high salinity content on both sides of the North Branch fault (CDWR, 1966).

Poland and others (1956) did not map the North Branch fault on Newport mesa. CDWR (1966) mapped two traces of what can be considered the North Branch fault; a queried and inferred fault to the north and a solid-line fault about 1.8 km to the south where late Pleistocene Lakewood Formation is offset (figure 2b). Miller (Miller and others, 1975; p.c., June 1985) did not find convincing evidence for a through-going fault on west Newport Beach mesa, based on close examination of upper Pleistocene deposits exposed in the bluffs. However, Miller did observe minor faults cutting the upper Pleistocene deposits. Some faults offset the base of the terrace deposits up to 3-1/2 meters in an apparent vertical separation. Miller did not observe evidence of significant lateral offset along these faults (i.e., different facies across fault or different thickness of beds across fault). Most of the faults Miller mapped had a more northerly trend than the principal fault zone, perhaps indicating (1) minor faulting related to uplift and warping of the mesa surface, or (2) secondary faulting away (north) from the principal trace of the Newport-Inglewood fault zone.

Guptill and Heath (1981) provided evidence of probable Holocene and possible historic surface fault rupture along the North Branch fault in Newport mesa (locality 8, figure 2b). At one site where late Pleistocene deposits are offset, the pattern of faulting is complex. A horst block of late Pleistocene sand is uplifted about 60 cm between two shears (figures 2b, 7; photo 3). Different facies across the fault indicate that lateral offset has occurred. A palesol is offset and cumulative vertical separation of about 50 cm has occurred across a B soil horizon. However, the complete soil horizon has not been preserved at this site.

Evidence of possible historic surface faulting was observed about 120 meters to the southeast along an east-facing cut slope (Guptill and Heath 1981) (figure 2b). A fault was traced from the base of the slope upward through late Pleistocene deposits. The fault vertically offsets a B soil horizon and older fill (figure 8; photo 4). A distinctive laminated fine sand, called "puddle deposit" by Guptill and Heath (1981), is thought to represent a former ground surface. Old, pre-1933 fill was placed on top of the puddle deposit; both are offset, the sand about 30 cm, down-to-the-west (figure 8; photo 4). Guptill and Heath (1981) concluded that these data document historical surface faulting on Newport mesa, probably associated with the 1933 Long Beach earthquake.

BOLSA-FAIRVIEW FAULT

The Bolsa-Fairview fault was originally zoned for Special Studies in 1976, based on mapping by CDWR (1968) (figure 2a). Poland and others (1956) first mapped a part of the Bolsa-Fairview fault. They inferred a fault in northern Newport mesa, based on water-well data that indicated an apparent vertical offset of at least 90 meters (north-side-up) of lower Pleistocene San Pedro Formation at a depth of about 240 meters and the presence of a hot spring (figure 2b). CDWR (1966) connected the inferred fault of Poland and others (1956) with a fault in the Talbert oil field (Santa Ana gap) mapped by Loken (1963) (figure 2b). Loken (1963) concluded that the fault west of Newport mesa did not offset Pleistocene deposits and the sense of offset was opposite (north-side-down) to the fault mapped by Poland and others (1956). CDWR (1966) reported that the Bolsa-Fairview fault in the Santa Ana gap was a partial ground water barrier in Pleistocene deposits, but the Talbert aquifer (lower Holocene) was not offset.

CDWR (1968) inferred the location of the Bolsa-Fairview fault in the Huntington Beach-Bolsa Chica area based on: (1) the topography on Huntington Beach mesa, (2) an inferred 3-meter vertical offset of the lower Holocene Bolsa aquifer, (3) differences in ground water quality in late Pleistocene deposits across the inferred fault, and (4) oil-well data northwest of Bolsa Chica mesa in the Sunset oil field.

The topographic evidence of recent faulting across Huntington Beach mesa is based mainly on a linear gully (locality 9, figure 2a). The fault passes through the Sulley-Miller sand pit (locality 10, figure 2a), where late Pleistocene deposits are exposed. Keaton (1975) reported that contorted, fine-grained sand beds were the only indication of faulting near the trace of the Bolsa-Fairview fault. Miller (Miller and others, 1975; p.c., June 1985) and WCC (1984) did not observe evidence of offset late Pleistocene deposits in this pit.

The inferred 3-meter offset of early Holocene deposits (Bolsa aquifer) in Bolsa gap was based on two water wells located about 760 meters apart (cross section H-H', CDWR, 1968). It is doubtful that this magnitude of displacement could be interpreted correctly from such little control. In Sunset gap, cross section E-E' shows the Bolsa-Fairview fault as concealed by all upper Pleistocene deposits and the upper section of lower Pleistocene deposits (CDWR, 1968). Oil-well data from the Sunset oil field indicates that subsurface faults in the vicinity of the surface trace of the Bolsa-Fairview fault do not offset deposits younger than early Pliocene and that there doesn't seem to be a through-going fault similar to the Bolsa-Fairview fault (Allen and Hazenbush, 1957). WCC(1984) concluded, based on a literature review and limited field checking that the Bolsa-Fairview fault is not a Holocene active fault and may be an artificial alignment of inferred fault features.

Several site-specific fault investigations, including trenching, have been performed along the Bolsa-Fairview fault since the fault was zoned for Special Studies (figure 2a; Table 1). Evidence of the Bolsa-Fairview fault was not reported in any of these investigations, although the quality of the investigations varied
(Table 1).

SOUTH BRANCH FAULT

Poland and others (1956) inferred the location of the South Branch fault across Huntington Beach mesa based on a gentle southwest-facing slope (or ramp) and "structural features" at depth (locality 11, figure 2a). They stated that geologic, hydrologic, and geochemical evidence neither supported nor disproved the existence of a fault in Pleistocene deposits. CDWR (1966) mapped the South Branch fault as offsetting late Pleistocene deposits, but concealed by early Holocene deposits (Talbert aquifer) in the Santa Ana gap (cross sections B-B', C-C', CDWR, 1966) (figure 2b). The South Branch fault is not a saltwater barrier.

CDWR (1968) inferred the location of the South Branch fault based on Poland and others (1956) (figure 2a). CDWR (1968) does not map the fault as offsetting the early Holocene Bolsa aquifer and there apparently was insufficient data to delineate the South Branch fault in Bolsa gap. Hazenbush and Allen (1968) mapped faults beneath Bolsa gap that are roughly parallel to the South Branch fault, but the faults do not offset units younger than lower Pliocene.

Glen Brown and Associates (1971) reported that a partial salinity barrier existed in the early Holocene Bolsa aquifer across the South Branch fault, based on pump test data from well BSO-1A (locality 12, figure 2a). WCC (1984) disagreed with the interpretation that the South Branch fault acts as a partial salinity barrier because: (1) well BSO-1A is located north of the North Branch fault, which is a salinity barrier, and (2) no other workers have reported that the South Branch fault is a salinity barrier in Holocene deposits.

Erickson (1976) trenched the inferred South Branch fault on the southwest end of Huntington Beach mesa (figure 2a). The trench, located just south of the Poland and others (1956) fault location, did not expose evidence of faulting. Erickson based the location of the trench on subsurface oil-well data, rather than topographic features. WCC (1984) inspected a gully for evidence of recent faulting along the inferred fault of Poland and others and also excavated a trench across the fault trace (figure 2a). No evidence of faulting in late Pleistocene deposits was observed. WCC concluded that near surface faulting in Pleistocene and Holocene deposits has not occurred along the South Branch fault.

R. Miller (p.c., June 1985) inspected the gully which delineates the inferred South Branch fault on the southwest side of Huntington Beach mesa. Miller did not observe evidence of a significant fault, although he did report a minor fault with a few centimeters of displacement in late Pleistocene deposits. Miller concluded that, although oil-well and near-surface hydrologic data do not support the existence of a significant fault, there may be a fault or faults in the subsurface which have produced warping in the mesa surface rather than surface fault rupture.

OLIVE AVENUE FAULT

The Olive Avenue fault was mapped as an inferred fault by Poland and others (1956) (figure 2a). No mention of this fault was made in the text of Poland and others, and it is not known what evidence was used to infer this fault. CDWR (1968) did not map this fault. Miller and others (1975) show this fault as concealed, based on Poland and others (1956) (figure 2a).

YORKTOWN, ADAMS AVENUE, AND INDIANAPOLIS FAULTS

Northwest-trending faults in Santa Ana gap mapped by CDWR (1966) include the Yorktown, Adams Avenue, and Indianapolis faults (figure 2b). These faults have been inferred mainly from hydrologic data. Early Holocene deposits are not offset along any of these faults; none are seawater intrusion barriers in the lower Holocene Talbert aquifer (CDWR, 1966). These faults do not offset the uppermost Pleistocene deposits, where they haven't been eroded (cross sections B-B', C-C', CDWR, 1966). Well-data points for control of interpretation of these faults is generally poor.

Through-going faults at depth were not mapped between Adams Avenue and the North Branch fault by Hunter and Allen (1957), indicating that the broad zone of faults mapped by CDWR (1966) probably has no counterpart at depth.

Additional faults mapped in the Santa Ana gap by CDWR (1966) (faults A, B, C) generally are poorly constrained by well data (figure 2b). These faults do not offset the Talbert aquifer (early Holocene).

SANTA ANA RIVER FAULT SYSTEM

A zone of discontinuous north- and northeast-trending faults on the east side of Santa Ana gap was mapped by CDWR (1966) (figure 2b). CDWR interpreted these features, which they called "stress relief" faults, based on changes in the mineral quality of ground water between Newport mesa and Santa Ana gap. CDWR stated that the nature and magnitude of these faults are not well known. None of these faults are shown to offset early Holocene deposits (cross sections A-A', G-G', and F-F, CDWR, 1966).

Additional published maps of the southern Newport-Inglewood fault zone include Morton and others (1973), Ewoldsen and others (1972), Ziony and others (1974), and Huntington Beach Planning Department (1974; based on Leighton-Yen and Associates, 1973). These maps basically are compilations of the mapping of Poland and others (1956) and CDWR (1966, 1968) and do not provide additional information.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the northwestern coastal Orange County study area was accomplished using Fairchild aerial photos (C-113, 1927, scale 1:18,000) and U.S. Department of Agriculture air photos (AXK, 1952, scale 1:20,000).

Approximately three days were spent in the study area in June and 1/2 day in September 1985 by this writer in order to verify, if possible, selected fault segments interpreted from air photos and examine fault exposures in Huntington Beach and Newport mesas. This writer was accompanied in the field by Paul Guptill on June 12 and W.C. Armstrong of the West Newport Oil Company on September 18. Field mapping in the study area is limited by intense development and the generally marshy conditions in areas that have not yet been developed. Results of field observations by this writer are summarized on figures 3a and 3b.

SEAL BEACH AND NORTH BRANCH FAULTS

The Seal Beach fault in the study area is moderately well defined in the Bixby Ranch Hill and Landing Hill areas (figure 3a). Fault traces mapped by this writer agree fairly well with faults mapped by Poland and others (1956), although the location of the fault in the very northwestern part of the study area differs by about 60 meters (locality 13, figures 2a, 3a). Geomorphic evidence indicating recent faulting includes scarps and troughs in late Pleistocene terrace deposits, possible closed depressions, and a possible right-laterally deflected terrace riser (locality 14, figure 3a). In addition, linear tonal contrasts further indicate the location of the fault (figure 3a). However, much of the ground surface on Bixby Ranch Hill had been modified by oil field grading since the early 1920's.

Geomorphic expression is generally lacking in late Holocene deposits in Alamitos and Sunset gaps (locality 1, 2, figure 3a). In Sunset gap two small hillocks, presumably underlain by late Pleistocene deposits, suggest a general location for the Seal Beach fault (figure 3a). At Hog Island, the possible location of the Seal Beach fault is delineated by a tonal lineament, linear drainage, and right-laterally deflected drainage in late Holocene deposits (figure 3c). However, the trend of these features is more northerly than the trend of the principal trace of the Seal Beach fault. Thus, these features could be a fortuitous alignment in saturated estuary deposits, or, possibly, they could be an en echelon fault break. Additional tonal lineaments and a possible graben suggest the location of the Seal Beach fault in Sunset gap, although these features may be the result of seismic shaking or, perhaps, are unrelated to tectonic processes (figures 3a).

The North Branch fault on Bolsa Chica mesa is delineated by a moderately well-defined, southwest-facing scarp, tonal lineament, and a closed depression in late Pleistocene terrace deposits (locality 4, figure 3a). The location of the fault mapped by this writer agrees well with the fault mapped by Poland and others (1956) and the faults exposed by WCC (1984). It is not clear whether the southwest-facing scarp has been formed only by recent faulting, or has, in part, been formed by erosion. The "downthrown" side of the fault is relatively flat, indicating that it may be a wave-cut bench. Thus, it is possible that the southwest-facing scarp is erosional.

Right-lateral strike-slip faulting is suggested by the right-lateral deflection of a drainage in Bolsa gap (locality 15, figure 3a). This right-lateral deflection coincides fairly well with the deep-seated fault zone mapped by Hazenbush and Allen (1958). However, supporting geomorphic evidence of recent faulting was not observed in Bolsa gap, so it is a tenuous assumption to conclude that recent faulting caused this deflection.

The North Branch fault is moderately well defined on Huntington Beach mesa, although oil field grading has locally modified the ground surface (figures 3a, 3b). The location of the principal trace of the North Branch fault described by WCC (1984) was confirmed by this writer on the west side of Huntington Beach mesa (locality 7, figure 3a). Here, near-vertical faults offset beds of late Pleistocene terrace and marine deposits. The strike of the faults vary from N40°W to N60°W (figure 3a; photos 1, 2). Soil-fault relationships were extremely difficult to interpret due to extensive animal burrowing and oil field grading. Geomorphic evidence of recent faulting across Huntington Beach mesa includes closed depressions, a left-laterally deflected drainage, pressure ridges in late Pleistocene terrace deposits, and associated scarps (figures 3a, 3b). The North Branch fault is discontinuous and forms a left-stepping en echelon pattern across Huntington Beach mesa.

The North Branch fault generally is not well defined in Santa Ana gap southeast of Huntington Beach mesa. A tonal lineament in Holocene alluvium and a possible closed depression align with the linear drainage on Huntington Beach mesa (locality 16, figure 3b), but farther southeast, the only evidence suggestive of faulting in Santa Ana gap is a weak tonal lineament in Holocene alluvium (figure 3b).

Geomorphic evidence of recent faulting on Newport mesa is very sparse, consisting of a vague, modified swale with associated tonal lineaments in late Pleistocene deposits (figure 3b). A prominent drainage across the southern part of the mesa is not offset (locality 17, figure 3b). The locations where Guptill and Heath (1981) found evidence of Holocene faulting are not characterized by geomorphic evidence of recent faulting, based on interpretation of Fairchild 1927 air photos. However, a field check of these sites by this writer verified the location of the faults (locality 8, figure 3b; photos 3, 4). The fault that offsets pre-1933 (?) fill can be traced down into late Pleistocene terrace deposits. Here, the fault appears to be normal; the attitude of the fault is N30°W 48°SW (figure 3b). However, the attitude of the fault where it offsets the B soil horizon and old fill is N32°W 85°NE, which differs from the N12°W attitude reported by Guptill and Heath (1981). The slope of the mesa bluff had been cut back at least 1 meter, so perhaps there is some variation in the fault plane surface. A trench excavated by W.C. Armstrong crossed Guptill and Heath's fault trace about 25 meters northwest of their site (figure 3b). The fault exposed in the trench offsets the B soil horizon. The fault trends N12°W and has a near-vertical dip.

An approximately 90-meter-wide zone of faults was observed by this writer along the southwestern side of Newport mesa (locality 18, figure 3b). The faults had relatively minor apparent vertical displacements of up to 1 meter. A small branch fault on the southwestern side of the zone appears to offset a soil unit similar to the paleosol at the "horst block" site described by Guptill and Heath (figure 7).

Additional, minor faults were observed in southern Newport mesa (figure 3b). A prominent soil profile has development on the mesa surface (U.S.S.C.S.,

1978) and this profile did not seem to be offset, based on very brief observations. However, it must be cautioned that many of the fault exposures are very subtle and very careful excavation and observations are necessary in order to satisfactorily determine recency or lack of recent faulting.

BOLSA-FAIRVIEW FAULT

The Bolsa-Fairview fault could not be verified in Bolsa Chica mesa and Bolsa gap, based on interpretation of 1927 Fairchild air photos. On Huntington Beach mesa the mapped fault of CDWR (1968) is delineated by a linear drainage and a left-laterally deflected drainage (locality 9, figure 2a). No additional evidence supporting recent faulting on Huntington Beach mesa was observed by this writer, based on interpretation of 1927 Fairchild and 1952 U.S.D.A. air photos (figures 2a, 2b). It is entirely possible that the linear and left-laterally drainages are formed by erosion. The location of the Bolsa-Fairview fault could not be verified in Santa Ana gap and Newport mesa, based on air photo interpretation by this writer.

SOUTH BRANCH FAULT

The inferred traces of the South Branch fault mapped by Poland and others (1956) and CDWR (1968) in Bolsa gap could not be verified by this writer, based on interpretation of Fairchild 1927 and USDA 1952 air photos. The location of the South Branch fault on Huntington Beach mesa is delineated by a southwest-facing slope, a very broad northwest-trending trough, and closed depressions (figures 2a, 2b). The closed depressions do not appear to be related to faulting, as there are a number of closed depressions on Huntington Beach mesa (figures 2a, 2b, 3a, 3b). Additional geomorphic evidence of recent faulting was not observed by this writer, based on air photo interpretation. The southwest-facing slope is quite gentle and could have formed from either broad warping of the late Pleistocene surface or wave erosion, rather than from discrete fault rupture events. The location of the South Branch fault in Santa Ana gap was not verified by this writer.

ADDITIONAL BRANCHES OF NEWPORT-INGLEWOOD FAULT ZONE

Additional branches of the Newport-Inglewood fault zone, including the Olive Avenue, Yorktown, Adams Avenue, Indianapolis, and the Santa Ana River fault system, could not be verified on Huntington Beach and Newport mesas, based on air photo interpretation by this writer (figures 2a, 2b).

SEISMICITY

The Newport-Inglewood fault zone is seismically active (figure 9). The 1933 M6.3 Long Beach earthquake occurred along the Newport-Inglewood fault zone approximately 5.6 km offshore from Newport Beach. No surface rupture was reported to have occurred during this earthquake, although considerable ground failure due to shaking (liquefaction, seismic settlement, lateral spreading) was reported (Barrows, 1974). WCC (1979) concluded that the best-fit focal mechanism for the 1933 Long Beach earthquake is right-lateral strike-slip along a N40^{o}W-trending, near-vertical fault with a focal depth of about 10 km. The average displacement at depth along the fault during this event (from seismic moment calculations) is 31 to 46 cm.

CONCLUSIONS

The Newport-Inglewood fault zone is a difficult feature to evaluate in terms of the hazard of surface fault rupture. The conclusions of Harding (1973) assume that the Newport-Inglewood fault zone is characterized by the wrench-tectonic style of deformation. This style of deformation, which Harding considered to be in the early stages of structural development (after Wilcox and others, 1973), is characterized by a complex pattern of generally discontinuous, left-stepping en echelon right-slip faults and associated anticlinal folding. Slip-rate calculations of 0.5m/yr by WCC (1979) further suggest that the surface expression of traces of the Newport-Inglewood fault zone is probably subtle. However, it is not certain how the late Quaternary slip-rate relates to the late Cenozoic slip-rate calculated by WCC (1979). If the slip-rate has remained relatively constant from late Miocene through late Quaternary time, one should anticipate that the geomorphic expression of individual strands along the Newport-Inglewood fault zone would be only moderately well defined at best. In addition, the soft, easily erodable Quaternary rocks and alluvium along the fault zone would not allow the preservation of ephemeral features that develop along strike-slip faults.

SEAL BEACH AND NORTH BRANCH FAULTS

Traces of the Seal Beach fault in Bixby Ranch Hill are generally only moderately defined in the study area due, in large part, to oil field grading that occurred in the early 1920's (figure 3a). The fault trace first mapped by Poland and others (1956) and zoned for Special Studies in 1976 seem to be mislocated about 60 meters to the northeast, based on air photo interpretation by this writer (locality 13, figures 2a, 3a).

The Seal Beach fault in Landing Hill is moderately well defined and is delineated by a northeast-facing scarp in late Pleistocene deposits (figure 3a). The fault first mapped by Poland and others (1956) and CDWR (1968), and zoned for Special Studies in 1976, was verified by this writer (figures 2a, 3a). Fault investigations by Davis (1981) and Fisher and Stoney (1983) exposed evidence of very latest Pleistocene (15,000 to 20,000ybp) faulting along the Seal Beach fault, although it was possible that the fault extended up into the modern solum.

The Seal Beach fault is poorly defined in late Holocene deposits in Alamitos gap (figure 2a). However, this is the principal drainage course of the San Gabriel River, and it is unlikely that geomorphic evidence of strike-slip faulting would be preserved for very long in an active floodplain environment. Southeast of Landing Hill, the location of the Seal Beach fault in Sunset gap is suggested by two hillocks presumably underlain by late Pleistocene deposits (localities 1, 2, figures 2a, 3a). Sunset gap is underlain by late Holocene floodplain and estuary deposits and propagation and preservation of surface fault features is probably unlikely. The features between Landing Hill and Hog Island mapped by this writer (figure 3a) may be related to surface faulting, seismic shaking, or normal sedimentation processes in an estuary environment. These features do correspond in a general way with the projected trend of the Seal Beach fault, but they are very weak evidence of recent faulting.

The North Branch fault across Bolsa Chica mesa is moderately well defined and Holocene faulting is suggested by a closed depression associated with a southwest-facing scarp (locality 4, figure 3a). WCC (1984) exposed evidence of Holocene-active faulting along the North Branch fault on Bolsa Chica mesa (figures 3a, 4). A thick B soil horizon is offset and, in trench T-2, the A soil horizon seems to be offset. However, the relationship between the fault and the A soil horizon was not clear on the opposite side of the trench (P. Guptill, p.c., June 1985). The A soil horizon is also offset along the North Branch fault, based on a cut slope exposure on the southeast side of Bolsa Chica mesa logged by WCC (1984). The sense of the vertical component of offset exposed in trench T-2 (WCC, 1984) is opposite to the down-to-the-southwest sense of vertical displacement indicated by the scarp on Bolsa Chica mesa. WCC (1984) concluded that this apparent inconsistency was best explained by predominantly horizontal offset of beds with lateral variations of thickness and dip. However, the southwest-facing scarp may not be entirely fault related, but rather a combination of faulting, wave erosion, and, possibly, surface warping.

The North Branch fault generally is poorly defined in Bolsa gap, although a right-laterally deflected drainage suggests the location of the fault (locality 15, figure 3a). WCC (1984) concluded that the width of the 275-meter-wide zone of faulting in Bolsa gap mapped by CDWR (1968) was not supported by oil-well data and the shallow water well data cited by CDWR. Also, this wide zone of faulting is not supported by the pattern of faulting observed on Huntington Beach mesa by WCC (1984) and this writer (figures 2a-2b, 3a-3b). Geomorphic evidence suggesting Holocene faulting along the North Branch fault in Huntington Beach mesa includes scarps in late Pleistocene deposits associated with closed depressions and a left-laterally deflected drainage (stream capture) (figure 3b). The fault is moderately well defined, and although discontinuous, WCC (1984) exposed evidence of late Pleistocene and possible evidence of Holocene offset along the North Branch fault on the west side of Huntington Beach mesa (figures 3a, 5, 6). A B soil horizon may be offset, but animal burrows and oil field grading have obscured soil/fault relationships.

The location of the North Branch fault in Santa Ana gap southwest of Huntington Beach mesa is problematical. The gap is underlain by late Holocene floodplain deposits of the Santa Ana River, so geomorphic evidence of recent strike-slip faulting probably would not be preserved for any length of time. A vague tonal lineament in Holocene alluvium may delineate the location of the fault (figure 3b). Guptill (p.c., June 1985) observed a linear tonal contrast near this location, based on interpretation of 1938 air photos. Early Holocene deposits reportedly are not offset in the subsurface along the North Branch fault in Santa Ana gap according to CDWR (1966). However, California Department of Water Resources' interpretations are limited to well and ground water data.

Guptill and Heath (1981) reported evidence of Holocene and possible historic surface fault rupture along a segment of the North Branch fault in Newport mesa (figures 2b, 3b). The location of these exposures is within 45 to 60 meters of faults mapped by DWR (1966) and Miller and others (1975) (locality 8, figure 2b). Although the offset fill was confirmed by this writer (figure 3b), the fault has a paucity of geomorphic features indicating recent faulting (figure 3b). It is possible that this fault rupture is associated with the 1933 Long Beach earthquake, but is a secondary rupture event north of a postulated principal fault located offshore of Newport Beach. On the other hand, the North Branch fault may be very complex and distributive in the Newport Beach area. Oil field data indicates that the fault zone changes to a more northerly trend in the Santa Ana gap area, perhaps producing faults with a greater component of normal offset. Cross sections of the West Newport oil field by Hunter and Allen (1956) tend to support this hypothesis. R. Miller (p.c., June 1985) concluded that the principal trace of the Newport-Inglewood fault probably lies offshore of Newport Beach and that the historic faulting reported by Guptill and Heath (1981) occurred along a secondary fault.

BOLSA-FAIRVIEW FAULT

The Bolsa-Fairview fault, partly zoned for Special Studies in 1976, was thought to be a right-lateral strike-slip fault (CDWR, 1966, 1968). CDWR (1968) mapped the fault as offsetting early Holocene deposits in Bolsa gap. However, this interpretation was based on two shallow water wells located about 760 meters apart (figure 2a). Direct observation of the Bolsa-Fairview fault has not been made. The fault was inferred through a sand pit (Sully-Miller quarry; locality 10, figure 2a), but evidence of faulting was not observed in late Pleistocene deposits by R. Miller (p.c., June 1985) and WCC (1984). Keaton (1975) concluded that contorted beds in late Pleistocene deposits represented the location of the Bolsa-Fairview fault, but discrete fault planes were not observed. Contorted sand beds are not necessarily formed by surface faulting, and it can be concluded that late Pleistocene faulting was not verified along the Bolsa-Fairview fault in Huntington Beach mesa. The geomorphic expression of the fault on Huntington Beach mesa and Bolsa Chica mesa is not well defined and those features on Huntington Beach mesa that suggest the location of the fault may be erosional (figures 2a, 2b).

Site-specific fault investigations along the Bolsa-Fairview fault did not expose evidence of recent faulting, nor the existence of a fault along the trace of the Bolsa-Fairview fault (Table 1, figure 2a). Oil field interpretations do not show a fault near the Bolsa-Fairview fault that offsets beds younger than early Pliocene. WCC (1984) concluded that there is no evidence that the Bolsa-Fairview fault is Holocene active and that the fault may be an artificial alignment of inferred fault features.

SOUTH BRANCH FAULT

The South Branch fault, first inferred by Poland and others (1956) across Huntington Beach mesa, was presumed to be a right-lateral strike-slip fault by CDWR (1966, 1968) (figures 2a, 2b). CDWR (1968) did not show the South Branch fault to offset early Holocene deposits. The fault is not well defined as a surface feature, based on air photo interpretation by this writer (figures 2a, 2b). The southwest-facing slope inferred to delineate the South Branch fault across Huntington Beach mesa is not sharp and may be completely erosional in nature, although it may be a broad, tectonic warp in the late Pleistocene surface . Site specific fault evaluations by Erickson (1976) and WCC (1984) did not expose evidence of faulting in late Pleistocene deposits. R. Miller (p.c., June 1985) concluded that oil well data and shallow water well data do not support the existence of a significant fault along the inferred trace of the South Branch fault, although he conceded that the southwest-facing slope could be a result of deep faulting manifested as folding at the surface. However, if recent folding has occurred, it is very broad, perhaps over 1 km in width.

OLIVE AVENUE FAULT

The Olive Avenue fault was inferred across Huntington Beach mesa by Poland and others (1956) (figure 2a). CDWR (1968) did not map this fault. Miller and others (1975) mapped this fault as concealed by late Pleistocene deposits (figure 2a). The fault was not verified by this writer, based on air photo interpretation.

ADDITIONAL BRANCHES OF NEWPORT-INGLEWOOD FAULT ZONE

Additional branches of the Newport-Inglewood fault zone mapped by CDWR (1966) include the Yorktown, Adams Avenue, and Indianapolis faults and the northeast-trending Santa Ana fault system (figure 2b). These faults, which are based on shallow water well data, do not offset early Holocene alluvium according to CDWR (1966), and none are seawater intrusion barriers. The faults were not verified by this writer in Santa Ana gap or on Newport mesa, based on air photo interpretation (figure 2b). Through-going faults at depth were not mapped between Adams Avenue and the North Branch fault by Hunter and Allen (1957), indicating that this broad zone of faults mapped by CDWR (1966) has no counterpart at depth. It is possible that most of the hydrologic conditions, interpreted by CDWR (1966) as representing faults, in fact would represent normal depositional conditions within an alluvial floodplain-estuary-littoral environment.

RECOMMENDATIONS

Recommendations for zoning faults for Special Studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

SEAL BEACH AND NORTH BRANCH FAULTS

Zone for Special Studies well-defined faults shown on figures 10a, 10b, and 10c. Principal references cited should be Poland and others (1956), CDWR (1968), Guptill and Heath (1981), WCC (1984), and this FER.

BOLSA-FAIRVIEW FAULT

Delete traces of the Bolsa-Fairview fault zoned for Special Studies in 1976 (figure 2a). Do not zone additional traces of the Bolsa-Fairview fault. These faults are neither sufficiently active nor well-defined.

SOUTH BRANCH FAULT

Do not zone. This fault is neither sufficently active nor well-defined.

ADDITIONAL BRANCHES OF NEWPORT-INGLEWOOD FAULT ZONE

Do not zone traces of the Olive Avenue, Yorktown, Adams Avenue, Indianapolis faults, and the Santa Ana River fault system. These faults are neither sufficiently active nor well-defined.

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Reviewed; recommendations approved. Earl Hart 11/6/85

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TABLE 1 - Summary of A-P Consulting Reports

Consulting Report DMG file	Fault Investigated	Fault Located ?	Recency Established	Remarks
Uhl (1975) AP-203	Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm. Trenches did not cross mapped trace of fault. No trench logs in report.
Eastman (1967a) AP-208	Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm. Trench did not cross mapped trace of fault.
Stone (1976) AP-247	Bolsa-Fairview	No	N/A	No evidence of faulting reported in Holocene deposits. Trenches crossed mapped trace, extended to 6' depth. Logs generalized.
Eastman (1976b) AP-250	Bolsa-Fairview	No	N/A	No evidence of faulting reported in Holocene (?) deposits.
Bell (1976a) AP-351	Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm.
Bell (1976b) AP-251	Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm. Trenches did not cross mapped trace.
Bell (1976c) AP-253	Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm. Trenches did not cross mapped trace.
Freeman, Benfer, and Merrill (1976) AP-399	Seal Beach	No	N/A	One 19-foot-deep trench excavated by drag line. No evidence of faulting reported in late(?) Holocene alluvium.
Bell and Hanson (1977) AP-411	Bolsa-Fairview	No	N/A	6 trenches excavated. TT-3 (sta. 1+00) had minor shearing in late Pleistocene(?) deposits, but fractures did not extend into overlying deposits, and it was reported that fractures did not extend below area shown in trench log.

TABLE 1 - Summary of A-P Consulting Reports

Consulting Report DMG file	Fault Investigated	Fault Located ?	Recency Established	Remarks
Powers (1978) AP-1793	Bolsa-Fairview	No	N/A	Trenches excavated, but none crossed mapped trace. No faulting reported in late Pleistocene Lakewood Fm. A trench to SE did cross fault (J.D. Merrill report #74284, 12-17-77). No fault reported in late Pleistocene deposits.
Cousineau (1979) AP-1794	Branch of Bolsa-Fairview	No	N/A	No evidence of faulting reported in late Pleistocene Lakewood Fm.

Photo 1. View northeast of borrow pit on northwest side of Huntington Beach mesa. Main trace of North Branch fault (arrows) was identified by WCC (1984) (see figure 5). The fault zone is about 25 meters wide at this location. Refer to photo 2 for detail of fault (A).

Photo 2. Close-up of fault segment delineated by arrow A in photo 1. Gravelly sand beds on right side of fault were not observed on left side of fault, indicating a significant but indeterminant amount of lateral or vertical offset. The trend of the fault is N60°W 87°SW; additional fault segments trend N40°W and have a near-vertical dip.

Photo 3. View northwest of 'horst block' exposed on Newport mesa (locality 8, figure 2b); pencil for scale. Trend of shears bounding horst block varies from N22°W to N30°W. Paleosol (arrows) and B soil horizon are offset. Refer to figure 7 for log of this feature.

← Photo 4. View north of offset pre-1933 fill on Newport mesa that was first described by Guptill and Heath (1981). The fault plane, delineated by white squares, trends N32°W 85°NE. Pre-1933 fill overlies 'puddle deposit' (arrows), a thin, laminated fine sand. This deposit, which overlies a B_{2t} soil horizon on the right side of the fault, was not observed across the fault. Light grey material at base of the exposure is late Pleistocene terrace deposits. Refer to figure 8 for log of this exposure. (Note: exposure had been cut back about 1 meter since the time of the Guptill and Heath log)

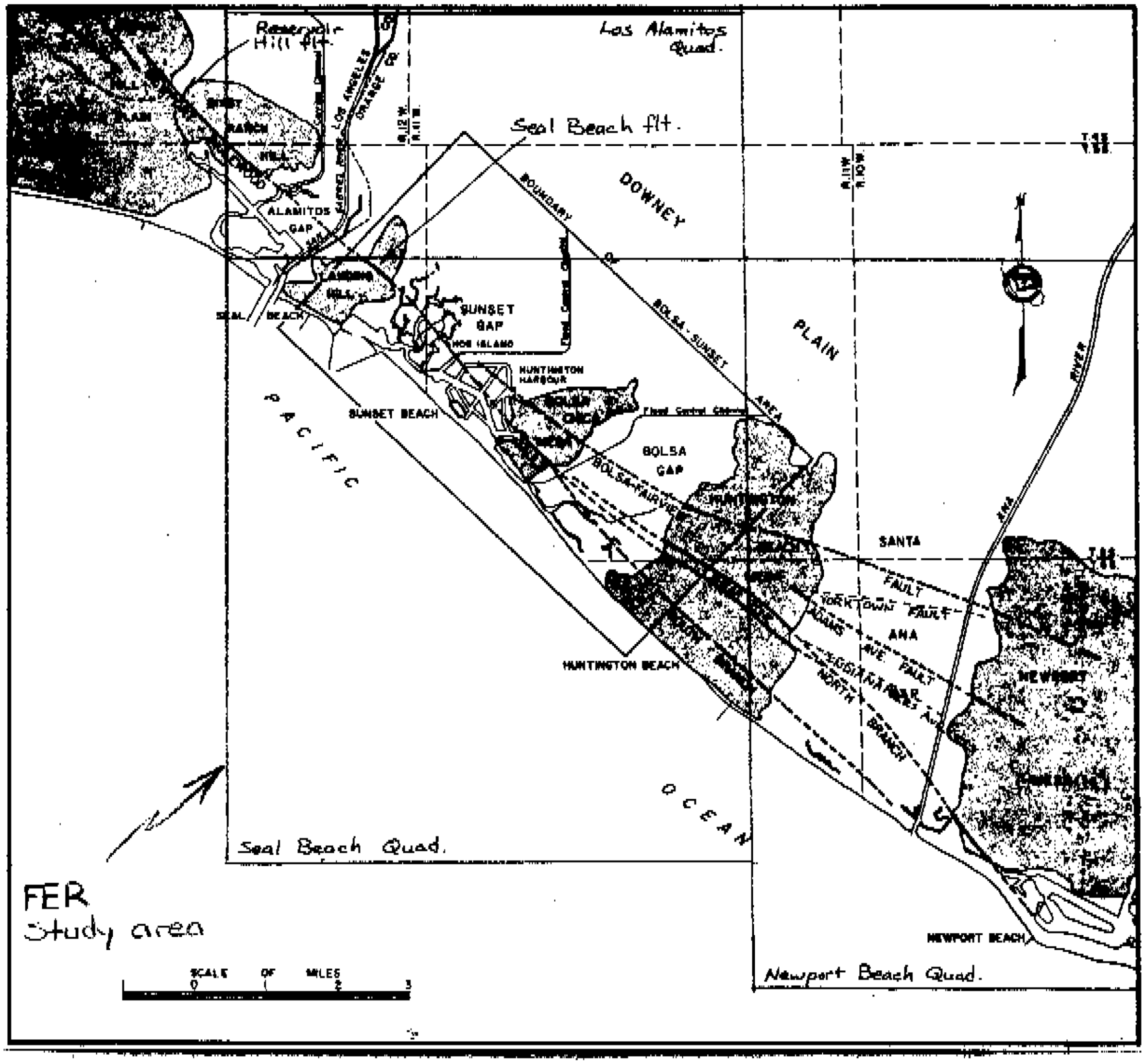

Figure 1 (to FER-172). Location of faults and physiographic features in the northern coastal Orange County study area. Map from CDWR (1968).

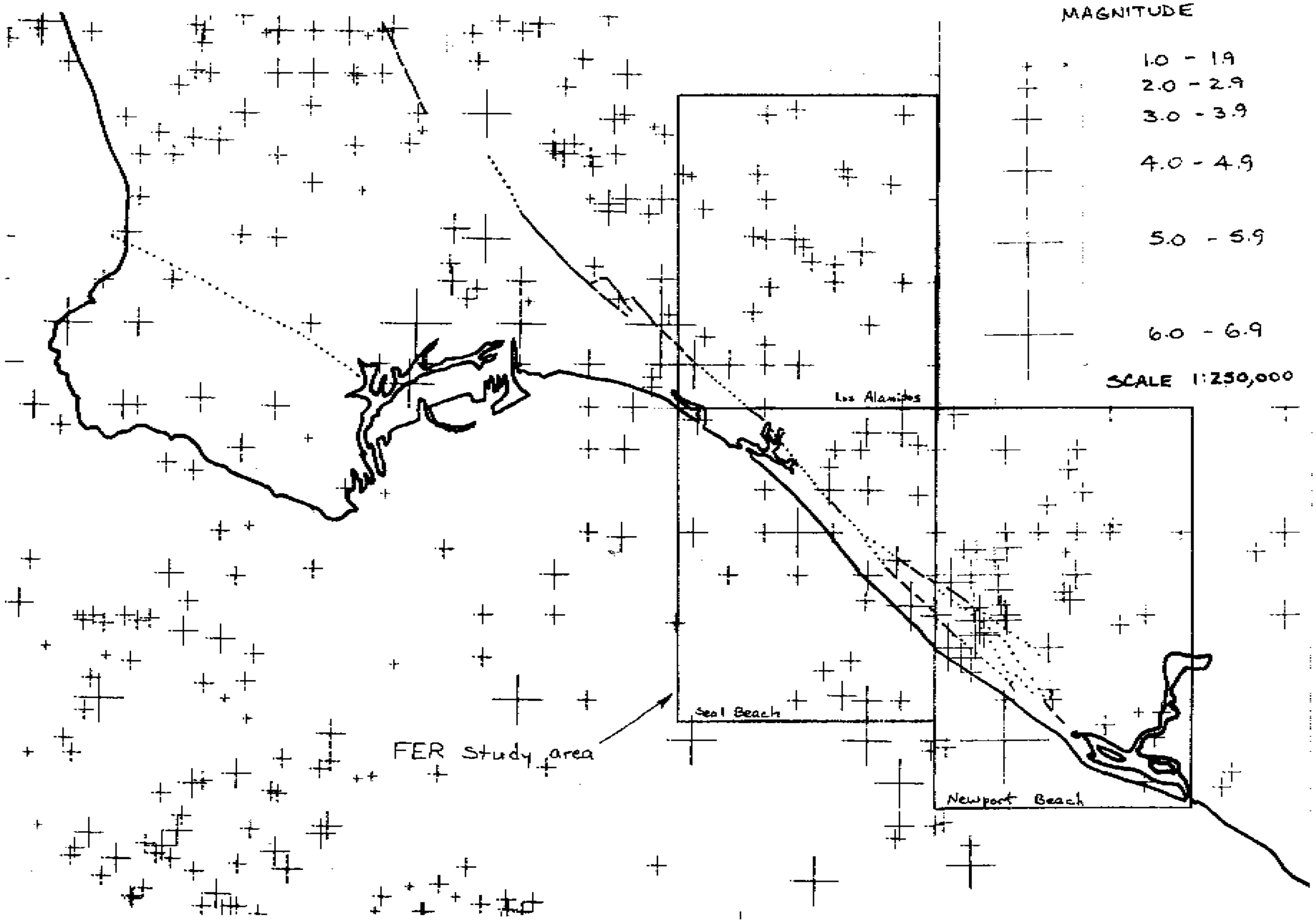

Figure 9 (to FER-172). Seismicity (A and B quality) in the study area for the period 1932 to 1984, based on locations from California Institute of Technology. Faults are from Jennings (1962) and Rogers (1965).